Circuit and PCB Design Report

Binary Logic-Based Blood Typing Device — Reader Electronics

Submitted for Design Review and Approval

1. Purpose of This Document

This document presents the complete circuit design (schematics) and printed circuit board (PCB) layout for the electronic reader unit of the Binary Logic-Based Blood Typing Device, developed with reference to U.S. Patent No. 12,605,703 B1. It is submitted for design review, so that the design can be approved before proceeding to prototype fabrication.

The document includes all schematic sheets, the PCB layout views, a summary of the components used.

2. Design Summary

The reader electronics are built around an ESP32-C3 microcontroller, four MAX30102 optical sensors (one per reaction zone), a TCA9546A I2C multiplexer, a USB-C powered charging and power-path system, and a result-indication stage. The design separates the reusable electronic reader from the disposable reagent strip, consistent with the patent's single-use, contamination-resistant cassette concept.

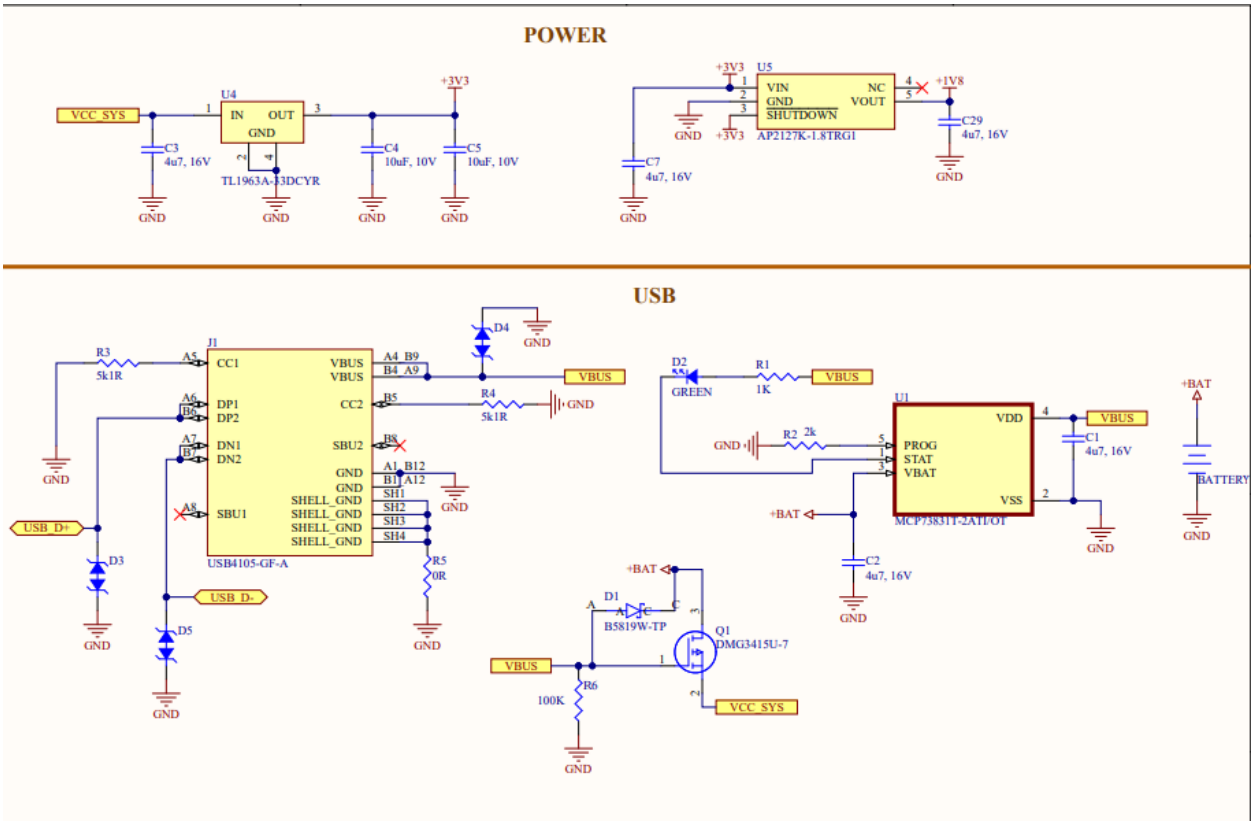
2.1 Updates Since Previous Review

- Result output changed from separate discrete LEDs to a single RGB LED, driven by three digital channels, producing one fixed color per ABO result.
- Sensor-to-zone assignment confirmed and fixed as: S1 = Anti-A zone, S2 = Anti-B zone, S3 = Anti-D (Rh) zone, with an additional S4 assigned to a control/validity zone.
- LED driver supply (VLED+) on all four optical sensors corrected to the 3.3V rail, separate from the 1.8V sensor core supply, in line with the sensor manufacturer's specified operating range.
- Sensor local ground (PGND) tied to system ground at each sensor individually, ensuring a complete return path for the optical LED driver current.
- I2C bus pull-up resistors confirmed present and correctly referenced: 3.3V on the main bus, 1.8V on each multiplexer channel, matching the multiplexer's voltage-translation configuration.

3. Circuit Schematics

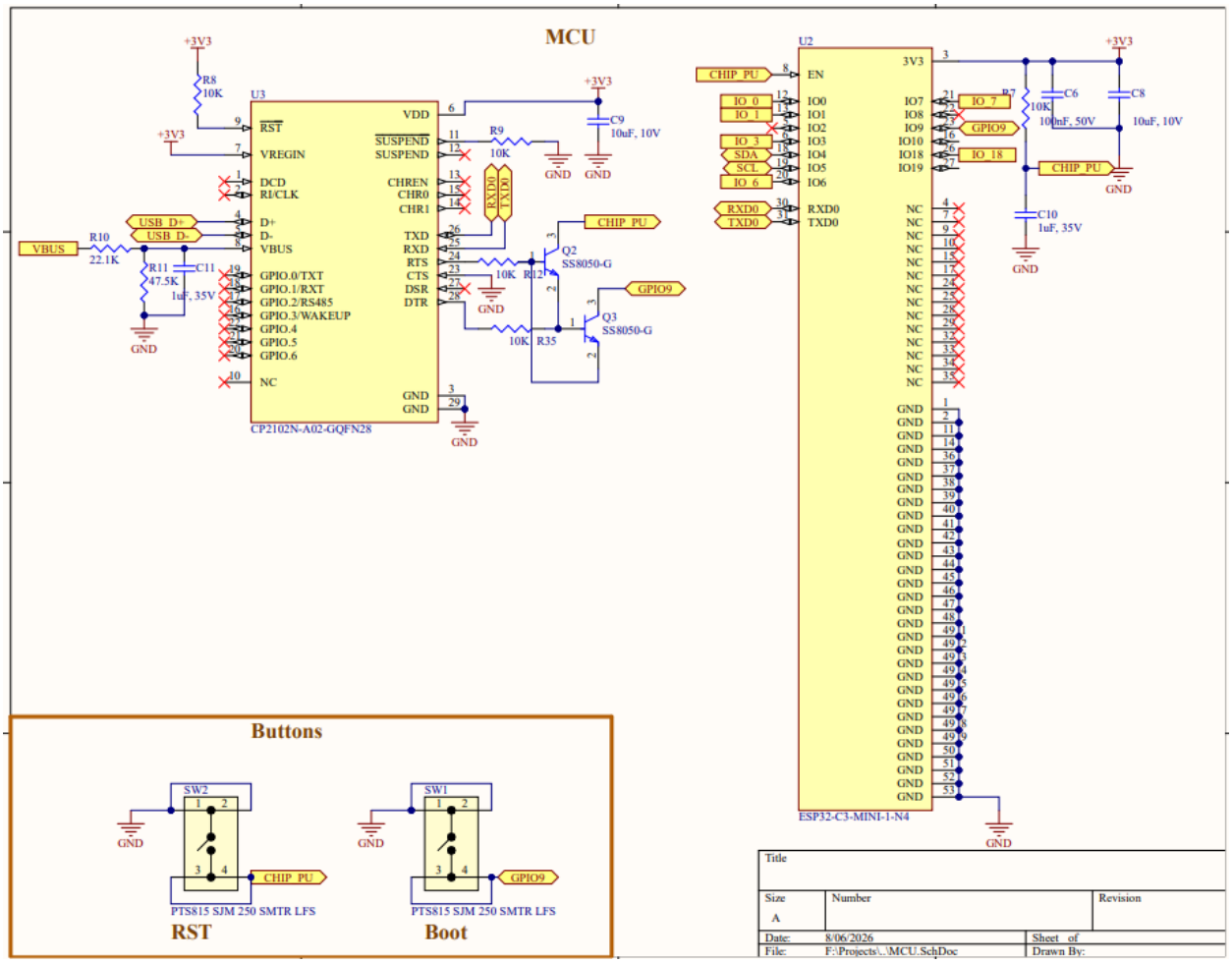
3.1 Power Management Sheet

Covers the USB-C input and protection, the MCP73831 battery charging circuit, the DMG3415U-7 power-path selection circuit, and the 3.3V / 1.8V linear regulators.



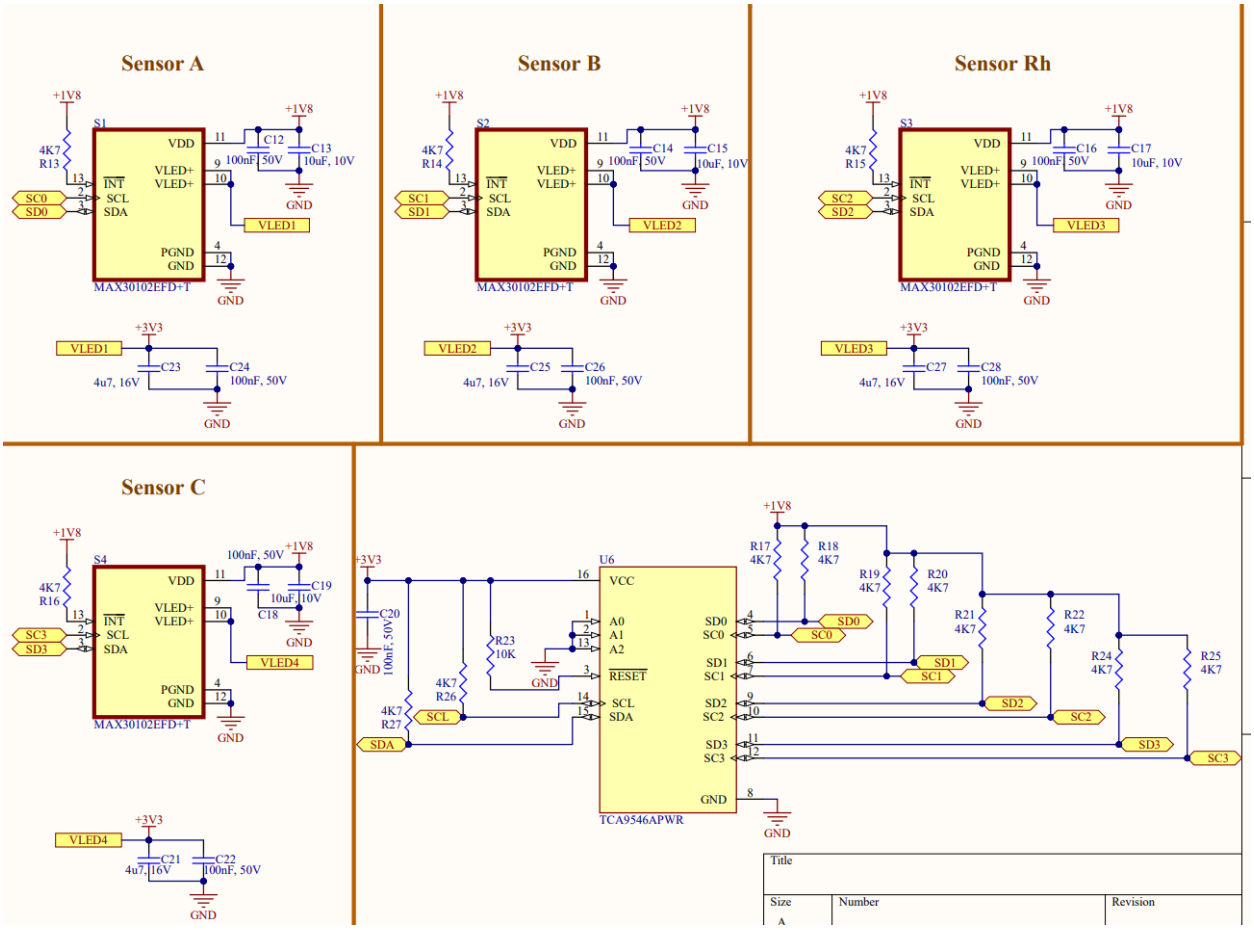
3.2 MCU Sheet

Covers the ESP32-C3-MINI-1-N4 microcontroller, the CP2102N USB-to-UART bridge, and the automatic reset/bootloader circuit used for firmware programming.



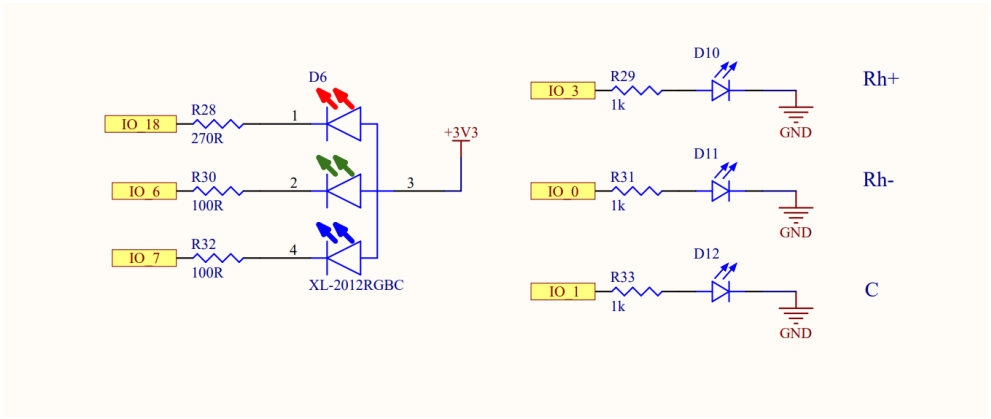
3.3 Sensor Sheet

Covers the four MAX30102 optical sensors (S1 = Anti-A, S2 = Anti-B, S3 = Anti-D/Rh, S4 = Control) and the TCA9546A I2C multiplexer that isolates each sensor onto its own communication channel.



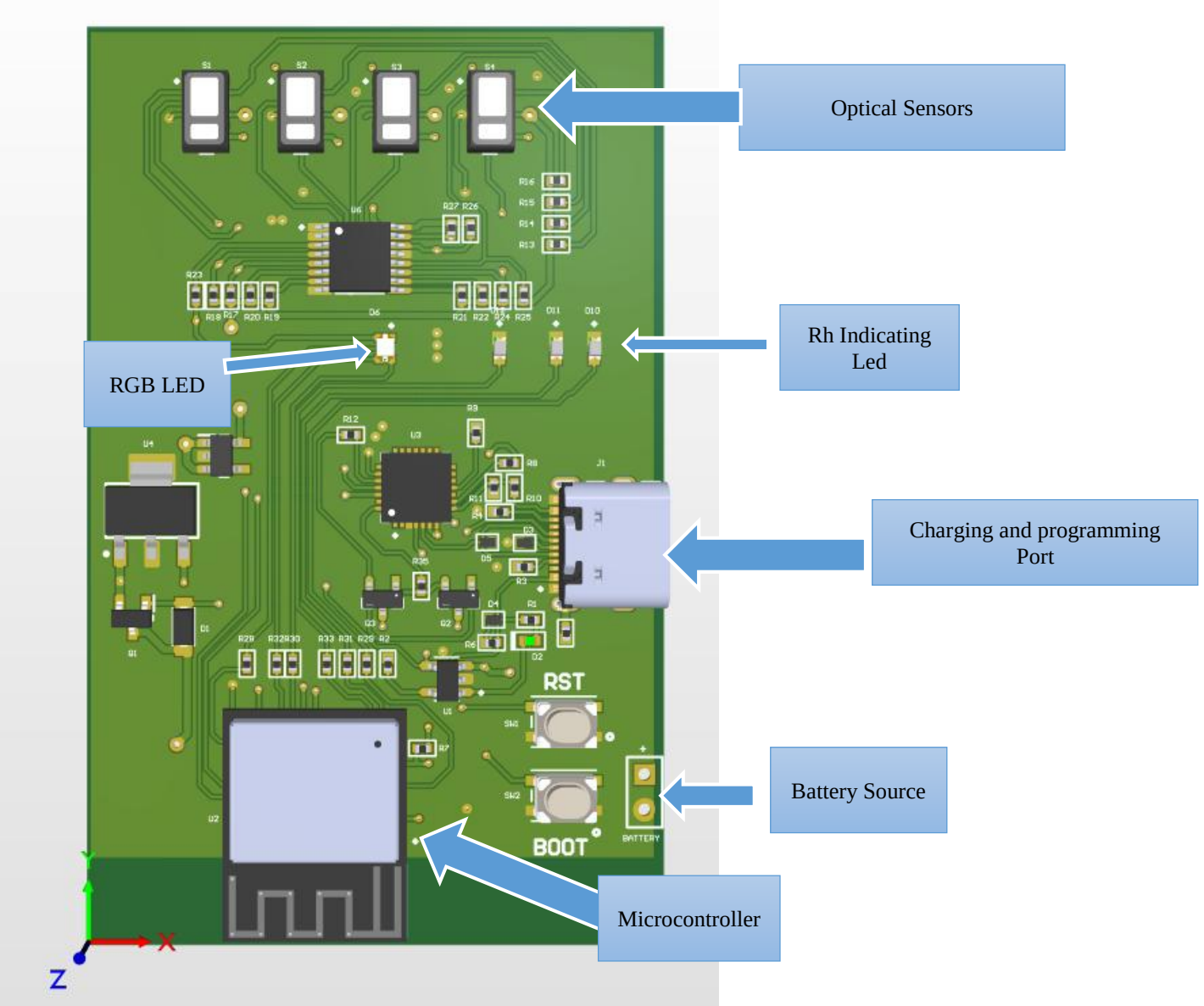
3.4 Result Indication Sheet

Covers the single RGB LED used for the ABO blood type result output, together with any supporting Rh and control-zone status indicators.



> ***Note:*** *The physical placement of the RGB result LED and the Rh/control indicator LEDs shown above is preliminary and included for reference purposes only at this stage. Final placement is subject to change based on the mechanical/enclosure design and may also be adjusted according to the client's requirements.*

4. PCB Layout



Board Dimensions

Length (mm)	67mm
Width (mm)	42mm
Layer Count	2

> ***Note:*** *The board dimensions above are to be finalised and filled in once confirmed. These values, along with the overall PCB outline, are subject to change based on enclosure requirements and may be adjusted according to the client's needs.*

5. Component Summary

Component	Part Number	Function
Microcontroller	ESP32-C3-MINI-1-N4	Runs the binary logic classification firmware; controls sensors, multiplexer, and result LED
USB-UART Bridge	CP2102N-A02-GQFN28	USB interface for firmware programming and debugging
I2C Multiplexer	TCA9546APWR	Isolates each optical sensor onto its own I2C channel
Optical Sensors (x4)	MAX30102EFD+T	Detect agglutination in the Anti-A, Anti-B, Anti-D, and Control zones
Battery Charger	MCP73831T-2ATI/OT	Manages Li-Po battery charging from USB-C
3.3V Regulator	TL1963A-33DCYR	Main logic and sensor LED-drive supply
1.8V Regulator	AP2127K-1.8TRG1	Sensor core supply
Power-Path MOSFET	DMG3415U-7	Selects between USB and battery power with minimal voltage drop
USB-C Connector	USB4105-GF-A	Charging and programming interface
Battery	BT1 (single-cell Li-Po)	Portable power source
Result LED	RGB SMD LED	Single-component blood type result output (A/B/AB/O)

6. Sensor-to-Zone Assignment

The following fixed assignment is implemented in the current design, matching the requirement confirmed in the previous review:

Sensor	Reaction Zone	Reagent
S1	A	Anti-A
S2	B	Anti-B
S3	Rh (D)	Anti-D
S4	Control	Control (no antigen reagent)

7. Result Output — Single RGB LED

The blood type result is displayed using a single RGB LED, driven by three independent digital channels (Red, Green, Blue) from the microcontroller. Each ABO result is represented by one fixed color combination, preserving a single, unambiguous digital output per test:

Result	Red	Green	Blue
A	ON	OFF	OFF
B	OFF	ON	OFF
AB	OFF	OFF	ON
O	ON	ON	OFF

Result O will be Yellow light and it is created in an RGB model through additive color mixing by combining **red** and **green** light at full intensity while keeping the **blue** channel completely off. A printed color-reference legend will be included on the device housing to ensure the result remains clear and unambiguous to the end user.

8. Design Verification Checklist

The following checks have been completed on the circuit design prior to submitting this report:

- USB-C CC1/CC2 pull-down resistors present for correct sink-device detection
- VBUS ESD/TVS protection and reverse-protection diode in place
- MCP73831 charging circuit matches manufacturer's reference application circuit
- Battery reverse-polarity protection and load switch correctly separated from the charging path
- Auto-reset/bootloader circuit verified against ESP32-C3 strapping pin requirements
- I2C main bus and per-channel pull-up resistors present and correctly referenced (3.3V / 1.8V)
- Sensor VLED+ and VDD supplies correctly separated (3.3V and 1.8V respectively)
- Sensor PGND tied to system ground at each sensor
- Decoupling capacitors placed at all major supply pins, including back-side placement with short vias where applicable
- No external crystal required; confirmed both ESP32-C3-MINI-1 module and CP2102N use internal oscillators

9. Request for Approval

This design is submitted for review. Pending confirmation of the items above, the intention is to proceed to PCB fabrication and prototype assembly.